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The Effect of Windspeeds on the Distribution Patterns of a Rain - Gun

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Summary

The uniformity of irrigation water applied with a rain gun was analysed under a variety of wind conditions during the summer of 1984. The optimum operation of a rain-gun is shown to be highly dependent on the wind. The effects of head winds, cross winds and diurnal variations in wind speeds are considered and the possible yield reduction due to non-uniform irrigation is discussed. A case is made for overnight irrigation.

Introduction

Following a dry summer an increase in interest in irrigation is to be expected. The very dry summer of 1976 was largely responsible for a dramatic increase in the area of land which can be irrigated in a dry season : 82,000 hectares in 1975 to 130,000 hectares in 1978 (MAFF, 1982). Substantial increases on the 1978 figure have occurred, especially in light of the persistent dry weather experienced during the summers of 1983 and 1984.

Rain-guns are widely used for applying irrigation water with the modern compensated reel-in, self propelled types becoming increasingly popular due to their reliability, low man-power requirement and relatively low capital cost.

Method

A popular type of rain-gun, the Wright Rain Touraine T66B/320 was investigated on five separate occasions during the summer of 1984. It was used to irrigate main crop potatoes and sugar beet on a farm near Lichfield, Staffordshire. The water was drawn by a 22.5 kw electric pump from a bore hole then piped to the irrigator.

The drive mechanism was full flow turbine with a pressure at the reel pressure gauge of 10 bars (145 psi). This gave a uniform reel-in speed on the pressure compensated reel of 4 min 35 sec per metre. The 19 mm (0.7") nozzle worked on a 300° rotation*. At this nozzle pressure the manufacturer's recommended centre spacing for over lapping runs was 54 m, so catches up to 27 m from the gun were of prime interest, although the whole distribution was measured to examine the effect of over lapping patterns more closely.

To collect the water, sharp rimmed plastic paint containers, mostly 5 litre, but some 10 litre ones at the extremities, were calibrated and positioned across the direction of pull at 3 m intervals. After each pass the catches were measured (usually by the farmer). The mean wind speed was calculated from hourly records at the Meteorological office at Birmingham Airport (recorded at the standard height of 10 m).

To quantify the results a technique used widely to determine the uniformity of application was employed. The "Christiansen Coefficient" of uniformity states:

$$Cu = 100 \left[1 - \frac{\Sigma /x - \bar{x}/}{\Sigma x} \right] \%$$ (Christiansen, 1941)†

Where x = catch in individual cans

$\bar{x}$ = mean catch of all the cans in the target area.

Hence a Cu = 100% would represent a perfect evenness of application, which, even with sprinkler application will never be achieved. For rain guns a grower should consider a value of 80% satisfactory. Many recent papers have critically examined the 44 year old coefficient ie Stern and Brezler (1983), Soloman (1984), but the coefficient is still considered appropriate when considering water application efficiencies.

* Information supplied by ADAS Mechanisation and Wright Rain

† A program has been written in BASIC for an Epson portable computer, to calculate the coefficient, with and without overlapping patterns. It is suitable for on-farm demonstrations.

Any shortfall in performance will be due to:-

1. wind speeds
2. wind directions
3. irrigator design and settings.
4. pressure variations
5. maintenance

The effect of each of these can be quantified following repeated trials under a variety of wind conditions. Of principle interest in this paper is the relative importance of wind speeds (head winds and cross winds) during each pass of the gun.

Results

Five sets of observations were completed at the farm during the 1984 season. The rain gun was pulled in an East to West direction, thus Northerly and Southerly winds were cross winds. The catches on each occasion are illustrated in figure 1; a summary is given in table 1.

Table 1 - Wind Conditions and Irrigation Distribution (No overlaps)

Date	Wind direction	Wind* speed (m/s)	Throw(m) South end/ North end	± 27 m spread Cu	± 27 m spread mean catch (mm)	whole spread† Cu	whole spread† mean catch (mm)
19 June	N	1.2	33/30	90	31.4	80	28.7
25 June	NW	6.2	30/18	40	32.7	28	29.6
5 July	SW to NW	1.3	33/33	82	35.1	68	30.6
16 July	NNW	3.6	33/27	63	39.4	44	33.3
18 July	NW to NE	2.7	42/39	88	33.7	65	26.7
			MEAN	73	34.5	57	29.8

* Mean during pass over the buckets

† including "zero" catches to equal distances on either side.

Figure 1 clearly shows the dramatic effect of windspeed on the distribution patterns. The catches taken on the 19 June and 18 July were under near ideal circumstances and show the near optimum performance of the irrigator. The pattern on the 25 June (the day of the ADAS Irrigation '84 exhibition!) shows the massive lateral shift in distribution with only a moderate wind blowing across the throw. Catches of up to 70 mm were recorded when an even distribution of around 35 mm was required. The windward side of the distribution was severely contailed by around 15 m without any increase in the distance of the down wind throw.

Previous ADAS studies into the performance of rain-guns are summarised in Annexe A.

Application Rates and Drift

On each of the 5 occasions under investigation in this paper the total volume of irrigated water falling onto the crop was calculated from the catch-cans and the results are given in Table 2.

Table 2 - Volume of Water on Irrigated Area

	Wind Speed (m/s)	Total Water m^3	Total Water Gallons
19 June	1.2	189	41,570
25 June	6.2	176	38,715
5 July	1.3	202	44,435
16 July	3.6	218	47,955
18 July	2.7	223	49,055

The stated application rate of 24.5 m^3/hour (5400 gallons/hour) when taken with the approximate time for the irrigator to pass the catch-cans (8 hours) gives a theoretical volume of 196 m^3. This agrees well with the mean of the observed values in table 2. The calibration of the rain gun was not verified so losses due to evaporation cannot be stated with any certainty. However, the additional loss of water due to drift during windy days can be derived from the mean volume on the low wind speed days (208 m^3) and the volume on the 25 June (176 m^3), ie an additional loss of 32 m^3 or 15%.

Overlapping Patterns

The Wright Rain irrigator was normally moved on a twenty four hour cycle. With changing wind directions and speeds it will be difficult to achieve neatly overlapping patterns to compensate for the fall-off in catches at the edges of the distribution. The recommended centre spacing of 54 m reflects this problem as, under near ideal conditions amounts of over 20 mm were evident beyond the 27 m point (Fig 1). If we now consider a pattern on a given day being repeated to overlap both edges as would be the case if identical irrigators were being run side by side with 54 m spacing then the distribution patterns so obtained are summarised in Table 3.

Table 3 - Wind Conditions and Irrigation Distribution (Overlapping Patterns)

Date	Wind Direction	Wind Speed (M/s)	± 27m Spread Cu	± 27m Spread Catch	Calculated Optimum Centre spacing (m)
19 June	N	1.2	81	37.6	66
25 June	NW	6.2	44	33.4	48
5 July	SW to NW	1.3	75	40.8	60
16 July	NNW	3.6	73	42.1	69
18 July	NW to NE	2.7	79	43.7	72
		Means	70	39.5	

Thus, with overlapping patterns at about 27 m from the gun, the application rates have increased and in effect raised the overall mean from 34.5 mm to 39.5 mm but the average uniformity of application has been reduced from Cu = 73% (Table 1) to Cu = 70%. This indicates that under these generally good conditions the recommended centre spacing was too small. The calculated optimum centre spacing on each day is shown in table 3.

Wind Effects : head winds, cross winds, diurnal variation

On the limited quantity of data so far collected the Christianson coefficient is strongly related to the mean wind speed during each run; see fig 2. With more data it should be possible to relate the cross wind and head wind components to the uniformity of catch. Cross winds will have the greater affect on the distribution in terms of a lateral shift (with the windward throw being most affected), whereas head winds may well "teardrop" the distribution without severely contailing the distribution on either side, (Blakeman, 1976).

Given a strong dependence on windspeed it is informative to study the diurnal variation of windspeed during the summer months. Fig 3 illustrates the marked increase in windspeed which may be expected between 0600 GMT and 1200 GMT. The windspeeds at heights lower than the standard recording height of 10 m will normally be less, but the height of the water-jet from rain-gun will be subjected to winds at heights approaching 10 m. The given values should therefore be a good guide.

In terms of uniformity of application, a doubling of the windspeed from, for example, 2.5 to 5 m/s will reduce the coefficient from 77% to 52%: see fig 2. The value of 52% is around the value observed on the 25 June, with catches varying from 0 mm to 71 mm. Such a huge variation in application will lead to problems in 1) runoff between the ridges and 2) underwatering and loss of yield.

Non-Uniform Irrigation and Yield Reductions

The literature on this subject is mosty theoretical and concerned with sprinkler irrigation where a relatively uniform distribution is to be expected.

The most commonly quoted values for uniformity are based upon above ground measurements. Several researchers have concluded that, if measured just below the soil surface, the uniformity of application is improved, although this is not always the case (ie Soloman, 1984). The more coarse nature of application via a rain-gun, as apposed for to a sprinkler system, will make sub-surface redistribution more difficult. Following the premise that the uniformity of applied water is indictive of the unformity of moisture in the root zone yield reductions will be experienced because:-

1. over watered areas will be subject to leaching of nutrients and waterlogging and;

2. plants in the under-watered areas will be liable to a degree of moisture stress.

The deleterious effect of large quantities of irrigation on potatoes has been demonstrated by Wolfe et al (1983). In a sprinkler experiment designed to, at most, maintain a soil at field capacity there was evidence of yield reductions due to "poor soil aeration and nitrogen deficiency" near the end of the season see Fig 4. These conditions are more likely to occur following less uniform applications of water.

The net effect of non-uniform irrigation has been demonstrated theoretically for sweet corn by Stern and Bresler (1983) see Fig 5. The effect of a poorer distribution with lower seasonal water requirements is important as in Britain the total water applied is unlikely to exceed 300 mm. In most years 150-250 mm will be adequate for main crop potatoes. From fig 5 it can be seen that 200 mm applied with a Cu of 80% will give 80% of the maximum yield. If the Cu drops to 60% (ie a value typifying irrigation under non-ideal conditions) then only 38% of the maximum yield can be expected. A similar relationship to that given for sweet corn will exist for other drought-sensitive crops.

A Case for Overnight Irrigation

The benefit of irrigating by night rather than by day has been demonstrated in terms of greater uniformity of application due to lower wind speeds. Over and above this, a reduction in the evaporation losses from airborne and leaf intercepted water drops can be expected to be around 10% of the applied water (but no reliable figure for this can be found in the literature).

Further, in many cases the cost of extracting and pumping the water will have to be considered. Not only will a 10% evaporative loss represent a total wastage of water, but also the fixed expense of pumping this water should be accounted for. Operating a 22½ kW pump for say 300 hours per season will consume 6750 kW of electricity. Utilising off-peak electricity at reduced rates would be an additional spin-off if irrigation can be re-scheduled to night-time whenever possible. The main disadvantage would be over the question of reliabiliy of the machinery. Fortunately breakdowns are rare and modern irrigators should have an automatic cut-off which operates in the event of a failure.

Conclusions

The distribution of water applied via a reel-in type rain-gun has been shown to be highly dependent on windspeeds. The direction of the wind will also influence the spread pattern but insufficient data has so far been collected to quantify this effect. The lateral shift in the distribution under moderate crosswinds (≤5 m/s) was well illustrated. Poor distributions of this nature will directly lead to large reductions in crop yield and quality.

The average catch over all the sets of observations, and following the recommended centre spacing, was 35-40 mm, a rather greater amount than has been found with other irrigators.

The wind disturbance of the irrigation pattern can be reduced by irrigating at night when the wind speeds are usually lower. Evaporative losses will also be much smaller during the night. Additionally, use can be made of off-peak electricity for operating the pumps, which will give a significant saving when pumping from deep bore-holes. Whether irrigating by day or by night mean wind speeds in excess of 2½ m/s (5½ mph) should be avoided if at all possible.

Key Words

Irrigation, Rain gun, Windspeed, Economics, Yield Reductions

Any comments or suggestions should be referred to the author.

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Annexe A - ADAS Rain Gun Performance Studies

Blakeman (1976) and Bailey during 1983* examined a wide range of rain guns, boom irrigators and centre pivot irrigators. Factors of performance recorded included water distribution, application rates, wind in speed and droplet size.

The comparable data to that presented in this paper has been extracted and is given below (also see Table 1 for comparison).

Distribution Patterns for a Variety of Rain Guns (No overlaps).

Type	Mean wind (m/s)	Actual Throw (m)	Effective Throw (m)	Actual Throw Mean Cu %	Actual Throw Mean Catch mm	Effective Throw Mean Cu %	Effective Throw Mean Catch mm
Dolphin 3/200*	Still	39/27	27/27	30	10.3	57	13.7
Dolphin 4/400*	1.5-2.0	48/57	42/42	56	22.1	80	27.4
Dolphin 4/400*	0.5-1.0	51/48	42/42	56	16.8	72	19.6
Javlin Irrifrance 82T	Still	39/33	30/30	46	22.0	66	26.4
Kaskad 110T	Still	37/35	37/37	90	20.3	90	20.3

Notes

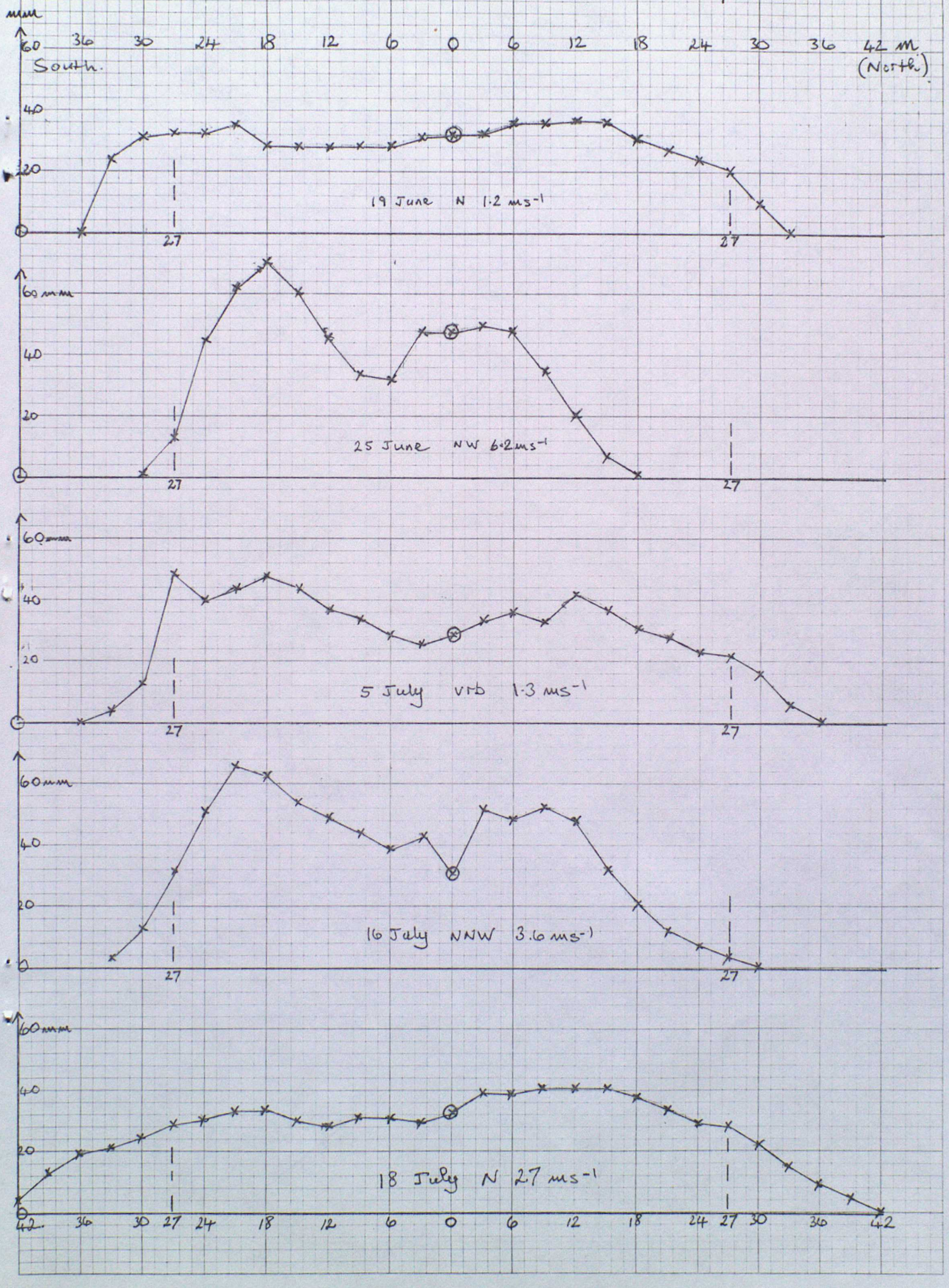
1. * indicates Blakeman T Bailey
2. The Javlin was operated at 40 psi above the recommended pressure of 83 psi.
3. The Farrow Dolphin 3/200 operated 25% below the recommended 85 psi.
4. The Farrow Dolphin 4/400 operated 13 psi below the recommended pressure of 71 psi.

The purpose of this table is not to provide a comparison of one type of irrigator against another. Rather, it is to indicate the problems which beset any such comparison when an irrigator is incorrectly set up. The Dolphin 3/200 is an excellent case in point.

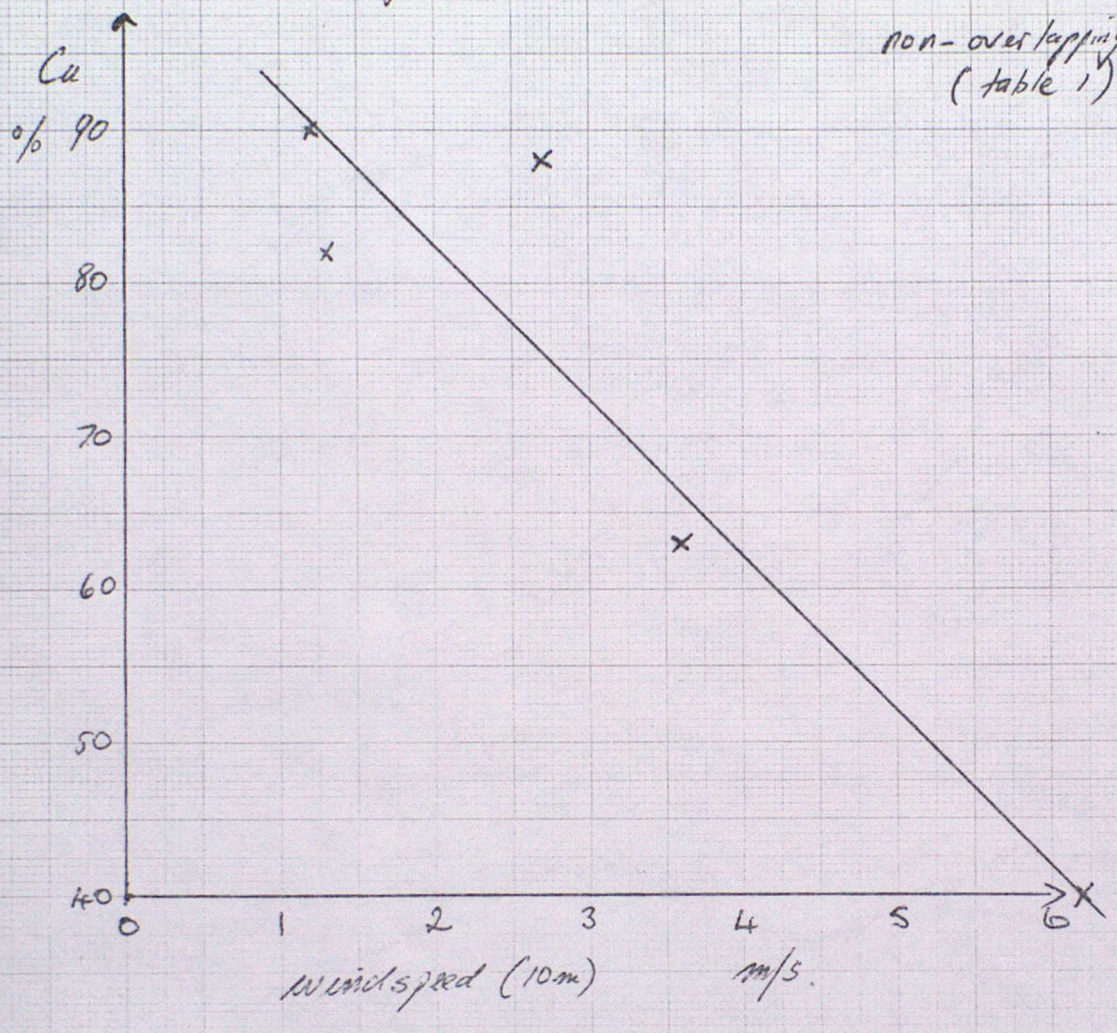
* Unpublished data supplied by ADAS Mechanisation.

FIGURE 1

DISTRIBUTION PATTERNS FOR TOURAINE T66 B/320



The Relationship between Windspeed and Uniformity of Application. Figure 2.



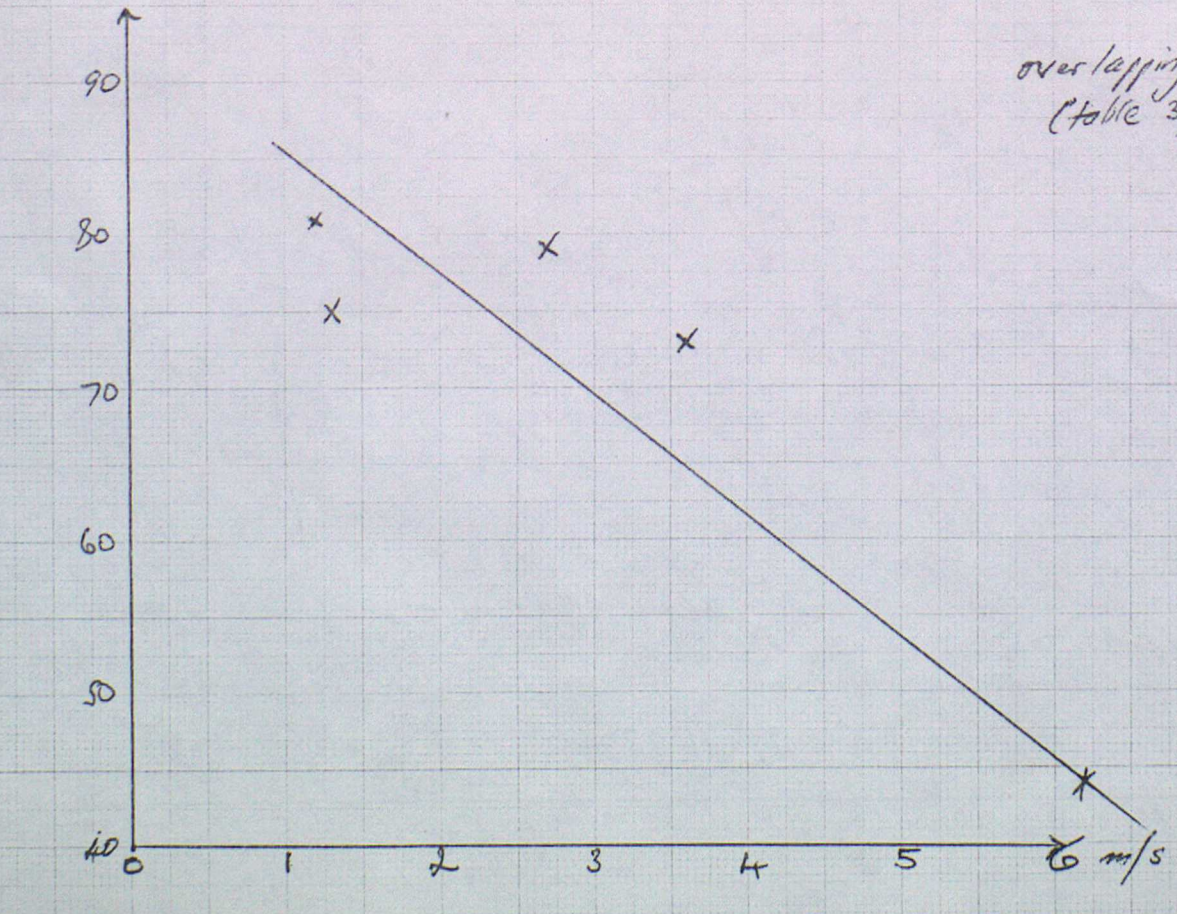


Figure 3

Mean Hourly Windspeeds : June/July.

Shawbury, Shropshire 1973-81

(Measured at 10m above ground.)

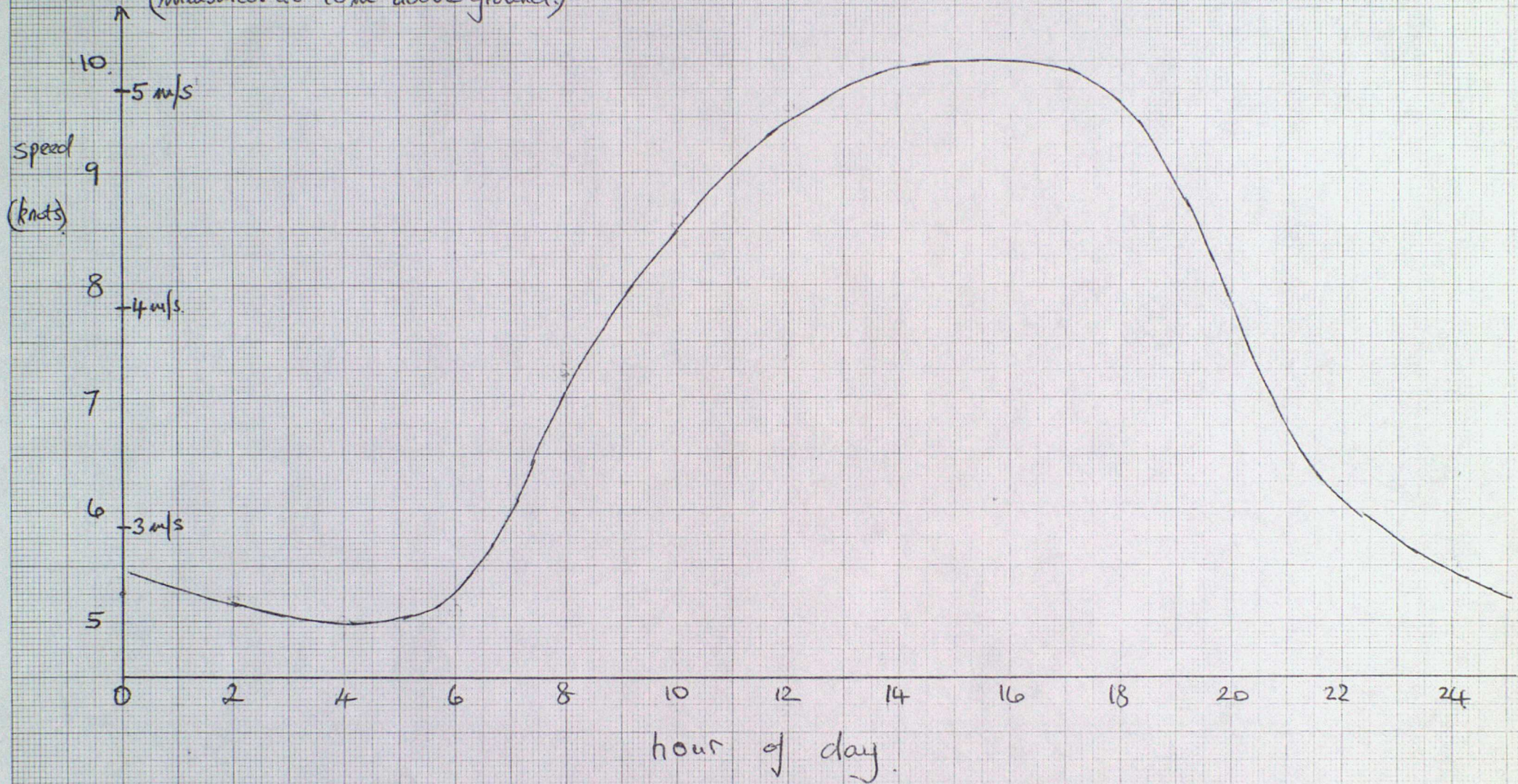
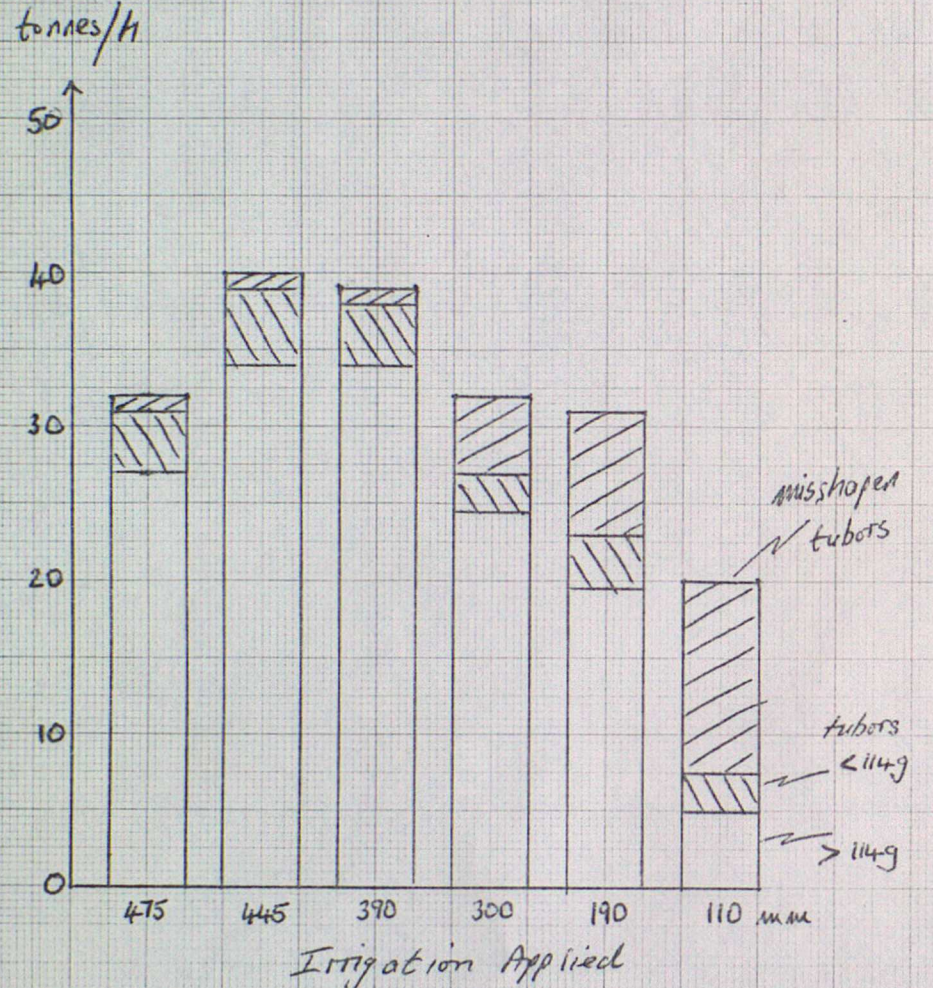


Figure 4

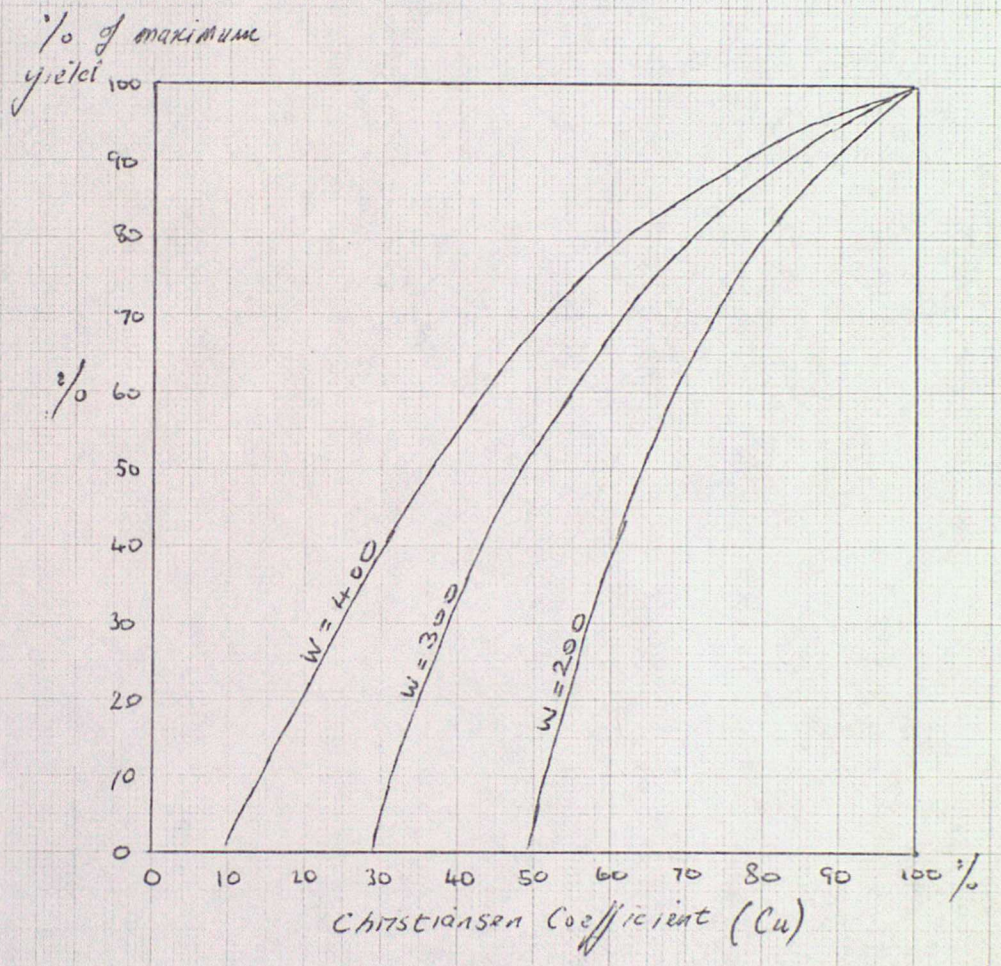
Fresh Weight yield of cv White Rose.



Wolfe et al (1983)

Figure 5.

Percentage of Optimum yield of Sweet Corn as a function of the Christiansen Coefficient.



W = total seasonal irrigation

Stern & Bleasdale (1983)